Improvement on LEACH Agreement of Mine Wireless Sensor Network

Yun-xiang Liu, Wei Zhang, Lan-feng Zhou
Computer and Information Engineering College, Shanghai Institute of Technology, Shanghai, China
E-mail: yxliu@sit.edu.cn

Abstract

Based on the characteristics of wireless sensor network communication in mine, LEACH protocol clustering is optimized, and the factors of energy and distance are considered fully. The selection of cluster head nodes is optimized, and a routing algorithm based on K-means ++ clustering is proposed. The problem of uneven distribution of cluster head nodes, uneven energy consumption and network stability in LEACH algorithm is improved effectively. Simulation results show that the proposed algorithm can improve the energy consumption of the whole network and improve the energy utilization rate, extending the network life cycle effectively.

Keywords: Wireless sensor networks, LEACH, K-means++, Mine

1. Introduction

Wireless Sensor Network is composed of a large number of data acquisition, data processing and communication capabilities of Sensor nodes to be self-organization formed a dynamic Network topology [1-3]. Which has a strong anti-destruction, self-adaptable and capable of rapid deployment and other advantages, it is widely used in important areas of industrial control, environmental monitoring, traffic control, health care, military and other [4-5]. Coal mining operations mainly in downhole and before the wireless sensor network has not been popular in the mine the wireline communication device is still in use. Wired communication there are some drawbacks, unable to pinpoint the underground site of the incident and the staff position when a security incident, coal ground personnel could not get the downhole specific information timely and accurately, it is not conducive to the underground work and security management.

According to the characteristics of the coal mine tunnel, the network topology is banded, and the communication environment is relatively poor. Same as the general wireless communications networks, the nodes work in some of the unmanned monitoring area, not easy to maintain and are limited and not renewable energy, so efficient, stable, energy-efficient routing protocol for the entire wireless sensor network is very important. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is widely used at present hierarchical routing [6-7], which can be applied to the general working environment. But for the special conditions in the mine under, LEACH protocol can't meet their requirements, therefore in this paper, we propose a route-based K-means++ clustering algorithm named LEACH-KPPE, to enable it efficient and stable to work in the mine environment. The clustering algorithm is optimized by K-means clustering algorithm, and fully consider the factor of energy and distance to control the selection of cluster head nodes. The problem of uneven distribution of cluster head nodes, uneven energy consumption and network stability in LEACH algorithm is effectively improved.

2. LEACH Protocol

LEACH protocol is the wider application of a hierarchical routing protocol in wireless sensor networks, the workflow is divided into two steps: generation and transmission of data clusters. The whole process will be repeated periodically, so that the process can be called a period of "round". In each round several more suitable node will be selected as a cluster head node from the network nodes randomly, before selecting cluster head, LEACH algorithm is given a pre-defined threshold value T(n), the threshold value is calculated as:

$$T(n) = \begin{cases} \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)}, & n \in G \\ 0, & \text{others} \end{cases} \quad (1)$$

Wherein p is the networks cluster head node proportion accounted for all the expectations, r is the current cycle of the number of rounds selected cluster head, G is a collection of which is not a cluster head node.

After completing the clustering work, the wireless sensor network begins to work. The nodes in the cluster begin to collect the required information, and then send the collected data to the head node within their cluster.

3. LEACH-KPPE Protocol

3.1 LEACH-KPPE algorithm basic idea

In this paper, a new LEACH-KPPE protocol is proposed based on the LEACH protocol for some defects of traditional LEACH applications in coal mines. LEACH-KPPE agreement in the main work process is same with the original LEACH basically, they are also cyclical round of reconstruction, and each round also includes two stages of the establishment of clusters and stable data transmission. In the cluster stage, the nodes in the whole network send their own position information and residual energy information to the base station. After the base station integrates the data, the K-means++ algorithm is used to cluster the nodes within the network area. After the K-means++ algorithm clustering processing, the clustering is complete. Next according to the quantity of the node residual energy and location information to decide the optimal cluster head nodes. After the completion of the establishment of clusters and the choice of cluster head there will be going on stable data transmission phase. In the LEACH-KPPE protocol not only retain the original single-hop communication, also joined the multi-hop communication.

Considering the correlation of meteorological factors and short-term load forecasting model based on historical load data, In this paper, the neural network input is mainly selected temperature and humidity meteorological factors, and then on the basis of the previous model this paper build a meteorological factors in the load forecasting model.

3.2 LEACH-KPPE algorithm implementation

3.2.1 The optimal number of cluster nodes

In this paper, by analyzing the traffic and energy consumption in the network, the optimal number of cluster head nodes can be obtained. There are M nodes in the erected wireless area, and they all be distributed in the N×N area. The number of cluster nodes is k, the whole network is divided into k clusters, each cluster has M/k-1 nodes, so the number of common nodes in each cluster is M/k-1. Multipath fading is used here, so the energy consumption of each cluster head nodes including receiving the rest of the nodes within cluster data information of power consumption, energy consumption of the data fusion and sends the data to base station:

$$E_{CH} = E_{elec}\left(\frac{M}{k}-1\right)b + E_{DC}\frac{M}{k}b + \varepsilon_{amp}{d_{CB}}^4 \quad (2)$$

Where E_{elec} is the energy consumption of transmitting or receiving 1bit data, b is the number of transmitted data, ε_{amp} is constant and associated with hardware, E_{DC} is the energy consumption of cluster head node fusion data, d_{CB} is the distance between cluster head node and the base station.

When the communication between a member node in a cluster and cluster head node, the member node is similar to the cluster head node, then use the free space model, then the energy consumption with a member of the cluster node in a round of work is:

$$E_{CM} = E_{elec}\, b + \varepsilon_{amp}{d_{CM}}^2 b \quad (3)$$

Where: E_{elec}、 b and ε_{amp} as above, d_{CM} denotes the distance between the member node and the cluster head node.

Assuming that the whole $N \times N$ area are circular and divided into k clusters, then the radius $R = N/\sqrt{\pi k}$. Assuming that the probability density of nodes in a cluster is $\rho\ (x, y)$, then:

$$E\left[{d_{CM}}^2\right] = \iint (x^2+y^2)\,\rho(x,y)\,dx\,dy \quad (4)$$

$E\left[{d_{CM}}^2\right]$ is the expectation of the square of the distance between the cluster member node and the cluster head node, by the radius $R = N/\sqrt{\pi k}$ available:

$$E\left[{d_{CM}}^2\right] = \int_{\theta=0}^{2\pi}\int_{r=0}^{N/\sqrt{\pi k}} \rho\, r^3\, dr\, d\theta = \frac{N^2}{2\pi k} \quad (5)$$

By the above calculation, in each round of energy consumption of each cluster are as follows:

$$E_T = E_{CH} + (M/k-1)E_{CM} \quad (6)$$

At this point the whole network has a total of k clusters, and the energy consumption in each round of E as follows:

$$E = kE_T = kE_{CH} + (M-k)E_{CM} = \Big(2ME_{elec} + ME_{DC} + k\varepsilon_{amp}{d_{CB}}^4 + M\varepsilon_{amp}\frac{N^2}{2\pi k} - 2kE_{elec} - \varepsilon_{amp}\frac{N^2}{2\pi}\Big)\, b \quad (7)$$

Because E_{elec} , E_{DC} and ε_{amp} is constant and independent of the k, so derivative the type (7) can get the extreme value of k with k_{opt} as follows:

$$k_{opt} = N\sqrt{\frac{M}{2\pi({d_{CB}}^4 - 2E_{elec}/\varepsilon_{amp})}} \quad (8)$$

In this way, the optimal number of cluster heads k_{opt} in the $N \times N$ region is obtained, that is the number of cluster centers k to be used by the K-means ++ algorithm.

3.2.2 Establish cluster stage

When building cluster, the information of location and residual energy of all the nodes in the area will be sent to the base station first, then use the K-means++ algorithm to cluster the nodes within the network. Its main working process is as follows:①The number k of optimal cluster centers is obtained by the above; ②For each node x within the region, to calculate the distance D(x) with the nearest cluster center;③Choose a new node as a new cluster center,;④Repeat ② and ③ until the election of the k cluster centers;⑤Calculate the dissimilarity of k cluster centers in the rest of the nodes; ⑥Re-update the k cluster centers by calculating dimension of all the nodes in each cluster;⑦Repeat steps ⑤ and ⑥ until the criterion function began to convergence. Establish the cluster of flow chart shown in figure 1.

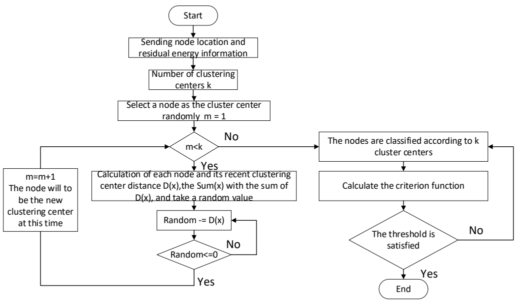


Fig. 1. Establish the cluster of flow chart

3.2.3 Stable data transmission phase

After the cluster head node selection and cluster work of the whole area is completed, the data transmission is started. Single-hop communication cannot meet the requirements of communications in coal mines, this paper based on single-hop communication and then use multi-hop mode for data transmission. Figure 2 and Figure 3 compare the LEACH and LEACH-KPPE inter-cluster communication.

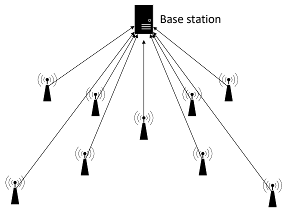


Fig.2. LEACH inter-cluster communication

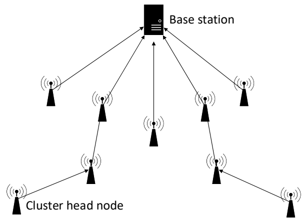


Fig.3. LEACH-KPPE inter-cluster communication

4. Simulation and Result Analysis

In this paper, the traditional LEACH protocol and the improved LEACH-KPPE protocol are simulated and analyzed in MATLAB platform. In this paper, $M = 100$ sensor nodes are distributed in the $100 \times 100m^2$network area. The parameters in the simulation are shown in Table 1.

Table 1 Simulation parameters

Parameter Name	Parameter Value
Base station location B	(50,120)
Node initial energy E_0	1 J
Transmit/Receive circuit energy E_{elec}	50 nJ$\cdot b^{-1}$
Power amplification factor ε_{amp}	0.0013 pJ$\cdot(b \cdot m^2)^{-1}$
Data fusion energy consumption E_{DC}	5 nJ$\cdot b^{-1}$
Packet length b	4000 b

From the above parameters, we can see that the distance between the cluster head node and the base station of d_{CB} is in the range of $50-130$, then we can know from formula (8) that the optimal cluster head number is related to the value of d_{CB}. The number of values ranges from $1 \leq k_{opt} \leq 4$. According to the parameters in Table 1, the relationship between the average energy consumption and the number of cluster head nodes k in the network is shown in Figure 4.

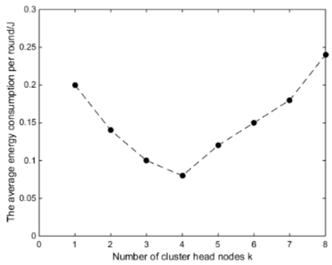
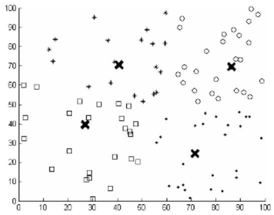
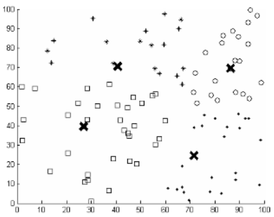


Fig.4. Relationship between cluster head node number and network energy consumption

Figure 5 shows the clustering simulation results of LEACH and LEACH-KPPE in one round. In Figure 5 (a) and (b), x represents the cluster center or the corresponding candidate node.



(a) LEACH-KPPE clustering results



(b) LEACH clustering result

Fig.5.The clustering simulation results of LEACH and LEACH-KPPE in one round

Figure 6 shows the relationship between the total energy consumption of the entire network and its operating time, which is represented by the number of rounds.

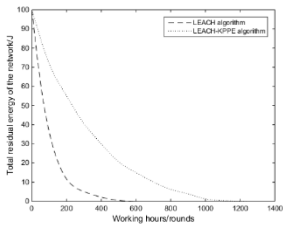


Fig.6. Network energy consumption curve

Figure 7 shows the relationship between the number of remaining nodes and their working time.

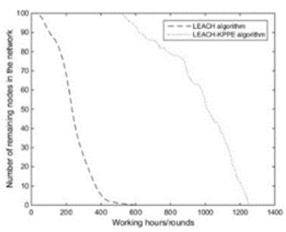


Fig.7. Network remaining node relationship diagram

5. Conclusion

In this paper, the K-means ++ clustering algorithm is used to improve the traditional clustering method of LEACH protocol, and the cluster head selection is optimized based on the energy of node and multi-hop mode is used between some cluster heads and base stations. LEACH-KPPE routing protocol, making it more suitable for wireless communications in coal mines. The simulation results show that the improved protocol has a significant improvement in terms of clustering results, energy consumption and node survivability compared with the traditional LEACH protocol, thus improving the network life cycle effectively and stability.

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